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STUDY REPORT
CAA-SR-96-8

ACTIVE, PASSIVE, ATTACK OPERATIONS, BATTLE MANAGEMENT/COMMAND, CONTROL, COMMUNICATIONS, COMPUTERS, AND INTELLIGENCE - PILLAR INTEGRATION (APAB-PI)

AUGUST 1996

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13. ABSTRACT (Maximum 200 words)

In 1995, the US Army Space and Strategic Defense Command and the US Army Concepts Analysis Agency recognized the need for a rapid response, low-resolution theater-level theater missile defense model. This report discusses how the Active, Passive, Attack Operations, Battle Management/Command, Control, Communications, Computers, and Intelligence - Pillar Integration (APAB-PI) model was developed to meet these objectives. The purpose of the APAB-PI Study was to develop a methodology and a supporting model which simulated all of the missile battles that together comprise the missile defense campaign for an entire theater. A process which allows the examination of the entire campaign enables analysts to answer decision makers' questions regarding the effect of different aspects of the tactical ballistic missile/theater missile defense on that campaign.

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ACTIVE, PASSIVE, ATTACK OPERATIONS, BM/C4I - PILLAR INTEGRATION	STUDY SUMMARY CAA-SR-96-8

THE REASON FOR PERFORMING THE STUDY was to develop a rapid response low-resolution theater-level theater missile defense (TMD) model.

THE STUDY SPONSOR is the US Army Space and Strategic Defense Command, P.O. Box 15280, Arlington, VA 22215-0280

THE STUDY OBJECTIVES were to:

a. Represent components of an integrated TMD campaign.

b Demonstrate the ability to conduct analysis of the TMD campaign using an established TMD scenario.

THE SCOPE OF THE STUDY was to develop a model using dynamic modeling techniques. The model was then applied to a current TMD scenario to demonstrate the methodology. Numerous sensitivity runs were made for verification and validation purposes. The model and methodology were applied to a Southwest Asia near-term scenario.

THE MAIN ASSUMPTIONS of this work are:

a. Dynamic modeling techniques can effectively represent integrated TMD.

b. The scenario selected to demonstrate the APAB-PI methodology accurately depicts likely circumstances under which US forces might become engaged in conflict in the specified timeframe. This includes the Allied and threat forces, US force structure and modernization, munitions availability, and strategic lift asset availability.

THE BASIC APPROACH was to use the dynamic modeling software to create a mental map (process flow representation) of the TMD campaign. As aspects of the model were built, they were verified for accuracy. The model/methodology was then applied to a near-term scenario which proved the concept and helped to validate the output.

THE PRINCIPAL FINDINGS of the work reported herein are as follows:

a. Pillar integration and the integration of joint and combined systems provide insights of the synergistic processes which cannot be determined by examining pillars individually and summing the results.

b. Dynamic modeling is a flexible process by which a constantly changing system, such as the TMD campaign, can be studied.

c. Mental mapping of a problem is a powerful way to identify and communicate a problem.

d. Dynamic modeling software is an appropriate tool for solving analytical problems.

THE STUDY EFFORT was directed and conducted by Mr. Karsten G. Engelmann, Extended Air Defense/Nuclear, Biological, Chemical Division, US Army Concepts Analysis Agency.

COMMENTS AND QUESTIONS may be sent to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-EN, 8120 Woodmont Avenue, Bethesda, Maryland 20814-2797.

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CHAPTER 1

EXECUTIVE SUMMARY

1-1. BACKGROUND

a. In 1995, the US Army Concepts Analysis Agency (CAA) sent a representative to GLOBAL, the annual Navy wargame in Newport, Rhode Island. GLOBAL is used by the Navy to examine warfighting issues of direct concern to the Navy and her sister services. One area of interest was the missile war between threat forces attacking US/Coalition forces, and defense against those threat forces.

b. To simulate the tactical ballistic missile (TBM) campaign and the TMD campaign, contractor and government personnel used the Extended Air Defense Simulation (EADSIM) Model. EADSIM is an engineering-level simulation that examines in great detail the missile battle. While it is an excellent model for simulating detailed aspects of the TMD battle, EADSIM is not an appropriate model to simulate the multiple missile battles which occur during a theater-level campaign.

c. The EADSIM Model generates very detailed reports regarding the TBM/TMD battle. However, EADSIM requires several analysts to execute even a simple scenario. The model is designed to examine only up to 12 hours of battle at a time. Further complications result because the completion of one missile battle does not set the simulation up with a new data set for the next missile battle. This information must be reentered into the data base. Further, changes to the input data base are both difficult and time-intensive. These factors make EADSIM an unacceptable model for theater-level wargames and simulations.

1-2. PROBLEM

a. Current theater missile defense (TMD) analytical tools do not adequately answer campaign-level TMD questions. Requirement studies and commanders need information based on an entire campaign, which often lasts for months. Yet a missile battle is often of short duration (minutes), with perhaps days between engagements. TMD is portrayed as a protective roof supported by three pillars (active defense, passive defense, attack operations) and an underlying battle management, command, control, communications , computers and intelligence (BM/C4I) architecture. It is through the proper combinations of the three pillars and a solid underlying architecture that TMD provides the optimal protection for the force. As a result, commanders need to know the optimal commitment of resources to each pillar and the base to ensure protection. Requirement studies examine how future acquisitions will affect the TMD campaign. Commonly asked questions regarding TMD include:

> What contribution does each pillar provide, by itself, to the overall TMD campaign?

What contribution does each pillar provide, in combination with other pillars, to the overall TMD campaign?

Which combinations of pillars provide the best overall TMD campaign?

How do aspects of deployment affect the TMD campaign?

b. As a result, CAA recognized the need for, and the advantages of, a low resolution, theater-level TMD simulation which examines various aspects of the TMD battle.

1-3. PURPOSE AND OBJECTIVES

a. Purpose. The purpose of the Active, Passive, Attack Operations, Battle Management/ Command, Control, Communications, Computers, and Intelligence-Pillar Integration (APAB-PI) Study is to develop a methodology and a supporting model which simulates each of the missile battles that together comprise the missile defense campaign for an entire theater. A process which allows the examination of the entire campaign enables analysts to answer decision maker's questions regarding the effect of different aspects of the TBM/TMD battle on that campaign. At the same time, the methodology and model must also simulate the individual interceptor-on-missile engagements.

b. Objectives. To develop a rapid-response, low-resolution theater-level TMD model to:

(1) Represent aspects of an integrated TMD campaign.

(2) Demonstrate the ability to conduct analysis of the TMD campaign using an established TMD scenario. The Southwest Asia OPLAN Analysis-PATRIOT Deployment (SOAP-D) Quick Reaction Analysis is an example demonstration of the APAB-PI model and methodology.

1-4. SCOPE. For the demonstration (SOAP-D), the Southwest Asia near-term campaign was examined.

1-5. LIMITATIONS. Because APAB-PI's objective is to be a rapid response, low-resolution theater-level TMD model, the methodology does not capture weapon systems characteristics in detail. Additionally, performance characteristics of future TMD systems are unknown and will be estimated from available operational requirements documents (ORD) and other sources.

1-6. TIMEFRAME. The scenario timeframe is current year (1996).

1-7. ASSUMPTIONS

a. Dynamic modeling techniques can effectively represent integrated TMD.

b. The scenario selected to demonstrate the APAB-PI methodology accurately depicts likely circumstances under which US forces might become engaged in conflict in the specified timeframe. This includes the Allied and threat forces, US force structure and modernization, munitions availability, and strategic lift availability.

1-8. STUDY APPROACH AND METHODOLOGY

a. The types of problems which APAB-PI is used to answer are dynamic, involving quantities that constantly change over time. Dynamic modeling accurately portrays constantly changing variables where feedback loops are critical and mandatory to understand the system relationships and to fully exploit the problem.[1] As a result, dynamic modeling was used as the fundamental simulation process for the APAB-PI model and methodology.

b. The basic approach consisted of forming analytical thoughts of how the TMD campaign is executed into a mental model of the process. Understanding of both the interceptor-on-missile engagement as well as resource allocation for the theater-level battle was necessary. Modifications were made to the model to represent the integration of the various pillars of TMD. Then, the mental model was mapped into a dynamic modeling program which converted the map into executable code to generate the campaign.

1-9. APAB-PI ESSENTIAL ELEMENTS OF ANALYSIS (EEA)

a. Is an analytical software package available to develop a low-resolution, fast turnaround TMD model?

(1) The I-THINK software package was evaluated and selected to satisfy the modeling requirements. With a top-down approach, the I-THINK modeling software allows an analyst to begin the development of a model at a low-resolution level. Then, as desired, detail can be enhanced for portions of the model while leaving other areas at low resolution. This model can perform 30 repetitions of a complete TMD campaign in under an hour. The program automatically generates graphical output, or tabular data appropriate for spreadsheets, data bases, or other software which uses tabular data.

(2) The software permits an analyst to draw a picture or mental map of the problem to be solved, or the process to be simulated. The software automatically informs a user, in a graphical way, when stocks, flows, or other entities are either undefined or improperly defined. The ability to separate processes into sectors allows the analyst to control the fidelity and play of various parts of the TMD campaign. Further, sectors permit sharing portions of the logic of the simulation between sectors, instead of generating an entire set of logic for each process desired to be simulated. The automatic conversion of the analyst's logic into code (readable by the user) eliminates the time necessary to learn a complex programming language.

[1] LTC Stephen Parker, Ph.D. Internal CAA memo, 11 February 1996

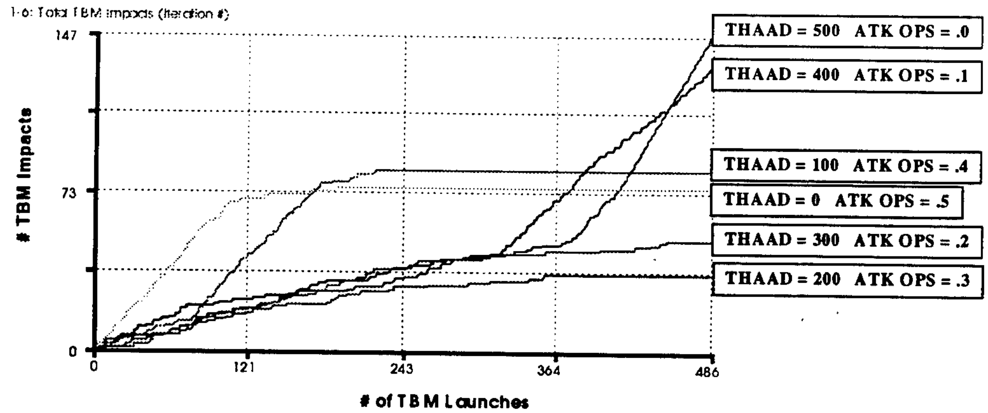
(3) Mentally mapping a process forces the user to identify, in a visual way, all those elements of a process which are important to simulate. It also allows for the communication of ideas within a working group and an easy way to connect work conducted by several analysts. Further, the mental map created can be presented to the customer to ensure that the analyst is examining those aspects of the problem of most concern to the customer. In addition, the results of the simulation can be explained more easily to the customer/decision maker.

b. Are there synergistic effects of integrated TMD pillars, and can they be measured?

(1) APAB-PI is designed to allow the analyst to examine any combination of TMD. This includes the addition of joint/combined systems. Pillar integration allows for the examination of two individual pillars on the battle, as well as identifying the synergistic effect which the pillars in combination provide. It also allows for sensitivity analysis between the pillars of one Service and of a pillar between the Services. Pillar integration and the integration of joint and combined systems provides insights of the synergistic processes which cannot be determined by examining pillars individually and summing the results.

(2) An evaluation of the integrated TMD pillars shows a strong synergistic effect. For example, the active defense pillar, under constrained resources, relies heavily on the attack operations pillar to destroy threat systems before active defense resources are expended. During a given campaign, active defenses will protect only until all interceptors are expended (time x). Attack operations will provide some defense, but by themselves will not protect the force until after a period of time (time y). By integrating the two pillars together, the analyst can determine if the timelines overlap if $x > y$, and thus the force is protected, or if there is a gap between when active defense assets are expended and when all threat systems are destroyed (if $x < y$).

(3) Figure 1-1 presents an example of the synergy between theater high altitude air defense (THAAD) and attack operations. In this hypothetical example, six sensitivity runs were made. In each run, the number of THAAD interceptors was decreased from 500 to 0. At the same time, the chance that attack operations would successfully destroy a launching transporter erector launcher (TEL) increased from 0 to 50 percent. The best situation (the lowest total TBM impacts) occurred when there were 200 THAAD interceptors available, and attack operations had a 30 percent chance of destroying a TEL.



THAAD: 500 - 0 (# of THAAD interceptors available)
ATTACK OPS: 0 - .5 (chance of destroying a TEL)

Figure 1-1. Synergy Between THAAD and Attack Operations

c. Can a low-resolution simulation of TMD adequately simulate the entire theater-level campaign at once?

(1) Dynamic modeling is ideal for representing constantly changing variables and quantities. Dynamic modeling elegantly simulates the effects of feedback loops and the changing variable influences on other variables. Because TMD has three pillars and an underlying architecture, dynamic modeling simplifies the process of understanding the ever-changing system relationships. Missile inventories oscillate over time, and the threat attack strategy is not static. Examination of graphs and tables of results over time provides added insights not obtained by evaluating the simulation only at its conclusion. Dynamic modeling has the flexibility by which a constantly changing system, such as the TMD campaign, can be studied.

(2) A low-resolution simulation of TMD can generate insights into the overall campaign that an interceptor-on-missile model cannot. For example, the speed of relocating interceptors from an area of surplus into an area of shortage will have an effect on the number of TBMs that penetrate the TMD. Resource considerations like this are at the heart of the theater-level campaign issues.

1-10. OTHER FINDINGS AND OBSERVATIONS. Several key findings regarding the simulation of TMD have been brought to light as a result of employment of the APAB-PI model/methodology.

a. System Deployment. APAB-PI was used by CAA to support planning staffs to optimize the deployment of current PATRIOT PAC-2 systems. In one case, representing a current situation, it was discovered that inadequate numbers of interceptors were planned to be in theater for defense. Additionally, there were insufficient defensive systems available to fully protect all critical assets. This requires the commander to decide between protecting a greater number of "critical" targets at a minimum level or protecting the most critical targets with additional assets.

b. Inventory Analysis. APAB-PI has been used by CAA to support the US Army Space and Strategic Defense Command (USASSDC) in generating inventory requirements for the PATRIOT PAC-3 (formerly called ERINT) interceptor. This effort examined the risk associated with various buy levels for given threats and scenarios. One observation from this effort is that the ability to move interceptors from areas of surplus to shortage will decrease overall risk to the campaign.

c. Active Defense. APAB-PI has been used by CAA to support SSDC's analysis of various active defense (lower-tier and upper-tier) architectures. One finding showed that active defense systems "buy" time for attack operations to destroy enemy TELs Another observation focused on how the number of upper tier interceptors affects defense. It identified that the quantity of upper-tier interceptors was a driving issue. APAB-PI also showed that even with a two-tier system, the defense is not perfect against incoming TBMs.

1-11. FOLLOW-ON WORK. The APAB-PI methodology and model represent a process which is constantly changing. New sectors are being added to the model which allow for direct analysis of the effects of a TBM when it impacts. Modifications are being made to allow for the examination of different theaters as well as new weapon systems. The success of the APAB-PI study effort has prompted continued requests for the application of the methodology and the adaptation of the model to new analytical efforts. Currently, outyear analysis of deployment plans for both Northeast Asia and Southwest Asia are being examined. Additional work is planned for current Northeast Asia operation plans (OPLANs). APAB-PI is also planned to support several wargame simulations at CAA. Each of these efforts will be used to enhance APAB-PI and to validate its process. APAB-PI is a living model, whose capabilities continue to grow.

CHAPTER 2

THEATER MISSILE DEFENSE

2-1. INTRODUCTION. This chapter describes the elements that comprise theater missile defense. It begins with an historical example of TMD, then it discusses each element of the TMD architecture.

2-2. DESERT STORM. Operation DESERT STORM demonstrated potential political and military impacts on the war plans of nations suffering TBM attacks. The United States and her allies were forced to commit multiple wings of what would have been deep strike/ground support aircraft to "hunt" for transporter erector launchers (TELs). Additional difficulties arose when threat forces attacked neutral Israel with ballistic weapons in an attempt to draw Israel into the war and disrupt the American-led coalition. To help protect Israel, missile defense assets were mobilized and deployed to Israel.

2-3. TMD PILLARS. As shown in Figure 2-1, TMD is represented as a protective roof for US forces. This roof is supported by the three pillars of TMD--active defense, passive defense, and attack operations. Underlying these three pillars is a coordinating base called battle management/command, control, communications, computers, and intelligence (BM/C4I).

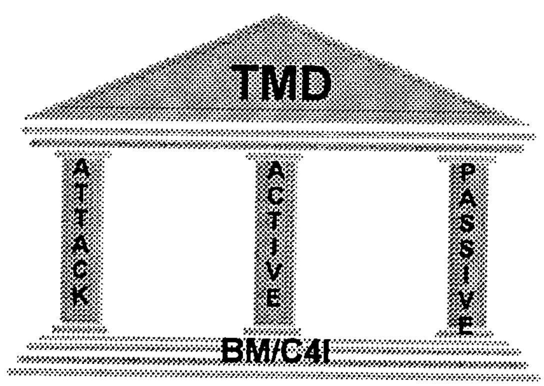


Figure 2-1. TMD Architecture

a. Attack Operations. Attack operations are those operations initiated to destroy, disrupt, or neutralize theater missile (TM) launch platforms and their supporting command, control, communications, computers, and intelligence (C4I), logistics infrastructure, and reconnaissance, surveillance, and target acquisition (RSTA) platforms. Attack operations forces include USAF and USN attack aircraft, the Army Tactical Missile System (ATACMS), the multiple launch rocket system (MLRS), attack helicopters, unmanned aerial vehicles (UAVs), and Special Operations Forces (SOF).

b. Passive Defense. Passive defense comprises those measures taken to reduce vulnerability and to minimize the effects of damage caused by TM attack. Passive defense includes TM early warning and weapons of mass destruction (WMD) protection, countersurveillance, deception, camouflage and concealment, nuclear hardening, electronic warfare (EW), mobility, dispersal, redundancy, recovery, and reconstitution.

c. Active Defense. Active defense includes those operations initiated to protect against a TM attack by destroying airborne TM launch platforms and/or destroying TMs in flight. Active defense forces currently consist of the PATRIOT antitactical ballistic missile system, which is soon to be upgraded to the PATRIOT Antitactical Missile Capability-Level 3 (PAC-3). The Army is developing the long-range Theater High Altitude Area Defense (THAAD) System to provide an upper tier defense against TMs. The PAC-3 system will provide a lower tier defense against TMs. The Medium Extended Range Air Defense System (MEADS), known formally as the corps surface to air missile, will provide a defense against TMs for tactical units. The Improved Hawk system is also being upgraded to give it limited antitactical ballistic missile (ATBM) capability for use by the US Marine Corps. The US Navy is developing sea-based lower tier (SM-Blk IVa) and upper tier (Light Exoatmospheric Projectile, or LEAP) TMD capabilities. The US Air Force is proposing a boost phase intercept (BPI) concept that could include either an interceptor missile, airborne laser, or both.

d. BM/C4I. TMD BM/C4I represents the integrated system of doctrine, procedures, organizational structures, facilities, communications, computers, and supporting intelligence. BMC4I includes missile warning and cueing of defense systems by missile warning sensors and ground stations as well as the entire suite of sensor and intelligence systems capable of supporting TMD. BM/C4I provides command authorities at all levels with timely and accurate systems and data to plan, monitor, direct, control, and report TMD operations.

2-4. PILLAR INTEGRATION. There is currently little formalized doctrinal or hardware integration of forces and elements representing the TMD pillars, even within the Services. Army attack operations and active defense forces are not fully integrated with existing sensors, C4I systems, and early warning systems to provide a synchronized response by all four components to a TM attack. As improved TMD capable systems become operational, military forces will require appropriate doctrine to define the communications architectures and protocols needed to employ Service capabilities in a timely manner, and the responsibilities of various components in responding to TM attacks.

CHAPTER 3

STUDY APPROACH AND METHODOLOGY

3-1. INTRODUCTION. This chapter describes the study approach and methodology. It also discusses the software program chosen to implement the methodology.

3-2. COMBAT SIMULATION MODEL USE AT CAA. The US Army Concepts Analysis Agency is designated as the Army's Center for Strategy and Force Evaluation. CAA is assigned the primary mission of assessing strategies, strategic concepts, broad military options, resource allocation alternatives, and analyzing Army force-level capabilities in the context of joint and combined forces. Computerized combat simulations are used by CAA to assess capabilities of forces engaged in conflict scenarios of interest to Army decision makers and to develop requirements for Army replacement equipment, personnel, ammunition, and support force structure. CAA often develops models to answer complex questions and employs the latest simulation techniques in developing the models.

3-3. APPROACH AND METHODOLOGY. The APAB-PI methodology focused on two goals--the simulation of the TMD engagement and the simulation of the TMD campaign. TMD engagement covers the aspects of an interceptor and a missile. The TMD campaign concentrates on resource allocation, optimization, and the effects of multiple missile engagements. The APAB-PI model portrays both, and integrates the engagements and the campaign together.

a. USASSDC and CAA recognized the need for a rapid-response campaign-level TMD model. The model needed to simulate a TMD campaign while still focusing on the interceptor-missile engagement. A study directive and an approach to achieve this was developed.

b. The study used a top-down approach to the analysis. The pillars of TMD were represented and then expanded. As each pillar was developed, sensitivity runs were conducted for that pillar independently. Then each pillar was examined in combination with other aspects of the TMD campaign at a generic level and then at a more detailed level (Figure 3-1).

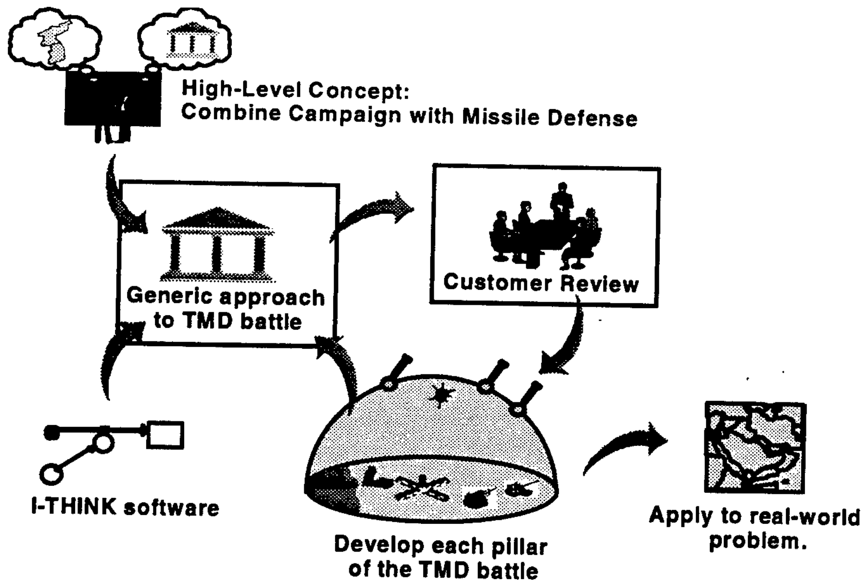


Figure 3-1. APAB-PI Methodology

c. As development of the APAB-PI model progressed, an immediate real-world application was identified, and the model/methodology were employed. A request was made of CAA to assist the US Army Central Command (ARCENT) to examine possible effects on a specific warfighting campaign scenario associated with the deployment of PATRIOT theater missile defense systems. The Southwest Asia OPLAN Analysis - PATRIOT Deployment (SOAP-D) Quick Reaction Analysis successfully employed the active defense pillar of the APAB-PI model. The effort, as mentioned by LTG Arnold, Commander ARCENT, "provided particularly valuable insights" including number of leaking missiles, location of leaking missiles, interceptors expended, TBMs intercepted, lift requirements, and closure times. This application provided a validation of the APAB-PI methodology. The SOAP-D analysis followed the methodology in Figure 3-1.

3-4. DYNAMIC MODELING SOFTWARE. CAA selected the I-THINK software package for the implementation of the APAB-PI model. The I-THINK software was chosen because it is cross-platform capable (Macintosh and PC), has a top-down approach, and has a fast execution. The I-THINK dynamic modeling software consists of: "an expansive, clean-slate construction site; a set of building blocks; tools for manipulating the building blocks; and objects to be used in organizing the construction site." The objective of I-THINK is to allow an analyst to use the software to construct operational maps that make explicit a mental model of how something works.

a. The concept of creating a mental model of the process allows an analyst to "visualize" the process. It can also help the analyst identify those elements of the process which have not yet been represented. This can be useful not only to the analyst, but also to working groups, customers, and decision makers. The flexibility of I-THINK software permits the analyst to map out the problem to be solved. This same visual representation is then presented directly as entered into the I-THINK software to the customer. This gives the analyst an ideal medium through which to explain how ideas were implemented. By being able to visualize the proposed process, changes to this mental model can be recommended by the customer.

b. Dynamic models use "difference equations" to approximate the answer. In difference equations, time is treated as a series of discrete, equally spaced units. This process allows for the simulation of short duration missile battles, with each missile battle affecting future battles in the campaign. To overcome the difficulty of long time intervals between missile battles, the difference equations are evaluated using each missile launch as a discrete event, with time being treated abstractly.

c. The analyst uses objects called building blocks (Figure 3-2) to develop the mental map of the process under investigation. There are four basic building blocks in the I-THINK software: stocks, flows (source/sink is part of the flow building block), converters, and connectors. It is with these four building blocks that all aspects of theater missile defense can be easily and quickly mentally mapped out.

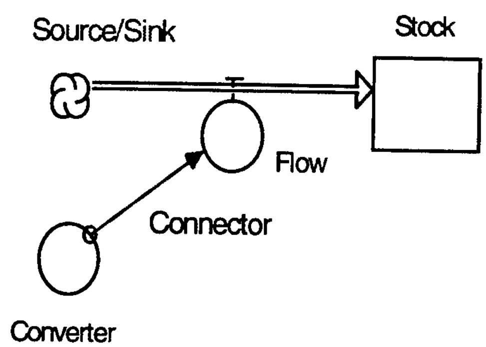


Figure 3-2. I-THINK Building Blocks

(1) Stocks represent accumulators. They store whatever flows into and out of them. There are multiple types of storage a stock can represent (reservoirs, conveyors, queues) with each type treating items (such as interceptors) in a different way. In the APAB-PI model, all the stocks currently represent reservoirs.

(2) Flows are used to increase or decrease the value of stocks. In addition, the direction on the map that flow's arrows points quickly informs the analyst which direction the flow is headed. Flows can be set to either only flow in, only out, or both flow in or out of a stock.

(3) The converter serves a multitude of purposes in the I-THINK software, and in the APAB-PI model. It can be defined as a constant, define external inputs to the model, calculate algebraic relationships, and serve as the repository for graphical functions. In general, it converts the inputs into outputs.

(4) The connector connects model elements. It is through connectors that elements of the model pass information.

d. Output defined in the I-THINK software package consists of definable line graphs, tables, and end point answers (Figure 3-3). The charts which can be automatically generated are of briefing quality. The tabular data can either be exported into a file format or copied and pasted into another program. The tabular data is reportable on any iteration interval. For example, if the analyst was concerned with the status of the campaign after every 10 missile launches, the tabular output can be set to report every 10 intervals.

Variable	# Available
ATACM MISSILES	12
THAAD MISSILES	100

Figure 3-3. End Point Answers

CHAPTER 4

THE ACTIVE, PASSIVE, ATTACK OPERATIONS, BM/C4I-PILLAR INTEGRATION (APAB-PI) MODEL

4-1. OVERVIEW. The APAB-PI model is designed to serve multiple purposes. The primary objective is the design and development of a methodology of low-resolution, theater-level (campaign-level) missile defense simulation. Flexibility is also a key element of the APAB-PI model. Adaptability is also fundamental.

a. The interception of a TBM traveling at speeds greater than a kilometer per second requires precision. Simulations of this interception require numerous inputs, must examine all factors, and will generate reams of output. APAB-PI uses averages from these simulations and the values from requirements studies to examine thousands of interceptions. This low-resolution examination of the missile battle allows the analyst to focus on theater-level issues that cannot be answered with a few-on-few simulation.

b. Not every interceptor fired will successfully destroy a TBM. This uncertainty is represented in APAB-PI as a stochastic process. Multiple iterations of the APAB-PI model using different random number sets will generate an average number of interceptions as well as the distribution. Through this stochastic process, the APAB-PI model uncovers average, best case, and worst case situations for the random sample.

c. APAB-PI uses campaign-level information and provides user-definable output from single interceptor-missile engagements to all the successful engagements for the entire campaign. For example, the effects caused by TBMs of a given type that are used in the model. The model is structured to allow for either high-level output (the total number of a type used), high-level output with a focus on certain areas (the total number of a type of TBMs used against airfields), or very detailed output (when each type of TBM arrived at a specific airfield).

d. . APAB-PI takes advantage of I-THINK's ability to simulate both sensitivity runs and "sector" runs. I-THINK allows an analyst to develop different portions of the model called sectors. Every variable within the APAB-PI model can be tested for its sensitivity to change.

e. APAB-PI uses the dynamic modeling ability of I-THINK to determine how the battle changes. Instead of each interval representing a small period of time (such as a minute or an hour), APAB-PI treats each missile launch as an interval. This allows for the evaluation of the battle by individual engagement and over multiple engagements.

f. During each interval, APAB-PI evaluates all sectors which have been turned on in order. If a sector of the model has not been turned on, then those calculations are not executed, and results are not calculated. A sample flow of the model for one iteration is described below.

4-2. OBJECTIVE. The objective of APAB-PI using I-THINK is to allow the analyst/ user/customer to develop a mental map of how the process works and, by describing the process, build a simulation. The process of TMD contains numerous steps (Figure 4-1). What follows is a description of how two of the pillars (active defense and attack operations) are represented and evaluated in the APAB-PI model.

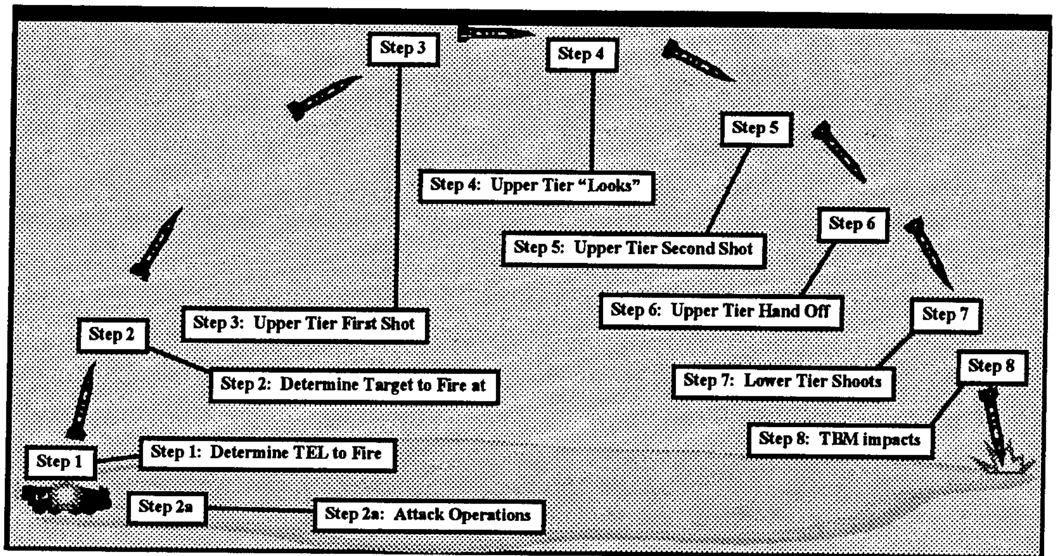


Figure 4-1. TMD Steps

4-3. APAB-PI INTERVALS. In the APAB-PI model, each interval represents one TBM launch. The model can represent an unlimited number of different TBMs. The first logic step the model executes is the determination of the type of TEL/TBM to fire. The launch of a cruise missile, fixed wing aircraft, or a UAV is also be considered "an event" for purposes of model iteration. Combined with ground launched TBMs, these comprise the category theater missiles, or the set of all missiles fired at surface targets. The type of TM fired, type of warhead carried, and whether it is targeted at a critical target (and what target it is fired at) is determined.

a. Step 1 - Determine TEL to Fire. The APAB-PI model begins an interval by determining which TEL and TBM type to fire. At the beginning of a scenario, the analyst decides if the model will use a predesignated firing plan (which may be read directly from a text file), or a random firing plan. For a random firing plan, the analyst inputs for each TBM type the number of TBMs and the number of TELs that fire those TMBs. At the start of each interval, the APAB-PI model determines which TBM will be launched based upon a weighted-random draw.

b. Step 2 - Determine Target at Which to Fire. For a set firing plan, the analyst informs the model for each interval what target at which it will be fired and if the target is considered "critical" to the Blue forces. For a random firing plan, the analyst enters firing priorities to the model. Based upon these firing priorities, previous launches, and the principle of diminishing returns, the model then determines which target to fire upon.

c. Step 2a - Attack Operations (Figure 4-2). After these first two steps to determine which TBM to fire and what target to attack, the APAB-PI model calculates the chance that US/Allied attack operations will detect the TEL or prepared TBM awaiting transport to the TEL. The attack operations "pillar" of the APAB-PI model is based on a spreadsheet model designed by SSDC, Huntsville. The attack operations process has both a pre- and postlaunch attrition determination as well as a capability to attack the threat infrastructure.

(1) The infrastructure attack capability represents the probability that US/Allied forces will succeed in locating elements of the threat TBM capability (for example, loading sites) prior to the threat's plan to attack. When a TBM loading or storage site is detected, the US/Allied forces attempt to cause attrition to the threat TBM stocks. While APAB-PI is a stochastic model, the probabilities are established such that over the course of the campaign, results generated are similar to the expected value numbers used in the SSDC spreadsheet model mentioned previously.

(2) Just before each launch, the APAB-PI model determines if the US/Allied forces detected the planned attack by the threat TEL and decides what response will be taken. If ATACMS missiles are available and a TEL is detected prelaunch, APAB-PI fires an ATACMS at the TEL and attempts to destroy the TEL or cause it to abort the mission.

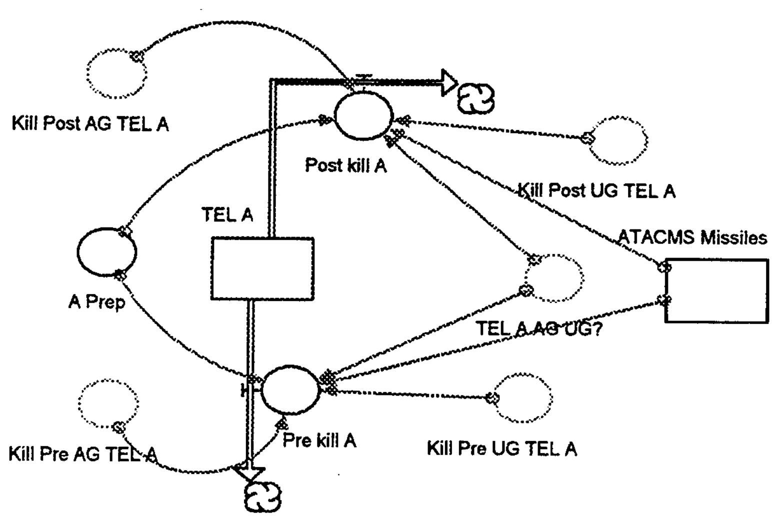


Figure 4-2. Attack Operations

(3) For example, if TEL type A was preparing to launch a TBM (A Prep), the model executes a check to determine if the TEL is detected before it launches. If the TEL was detected, there is a chance that the TEL will be destroyed. Success against a specific TEL is dependent on TEL type, whether the firing TEL is above ground (AG) or under ground (UG) and if there is at least one ATACMS missile available (ATACMS Missiles). If these are all true, then with a given ATACMS kill probability, the model determines if the TEL is destroyed before the TBM is launched.

(4) The logic input by the user flows from the mental map generated to describe the procedure. First the user checks to determine if the TEL is above ground or under ground. For each instance a kill draw is made against the TEL. At the same time, the user has told the model that unless a TEL is attempting to launch, it cannot be destroyed in the prelaunch phase. Finally, the user has set up a check to ensure that there is an ATACMS missile available. The lines below represent how the user, after examining the mental map, set up the logic of how the possible prelaunch destruction of the TEL would work.

*(IF (((Kill_Pre_AG_TEL_A = 1) AND (TEL_A_AG_UG? = 1)) OR ((Kill_Pre_UG_TEL_A = 1) AND (TEL_A_AG_UG? = 0)) * A_Prep) = 1 THEN 1 ELSE 0)**
(IF ATACMS_Missiles>0 THEN 1 ELSE 0)

(5) In an adjacent block of the model, the postlaunch logic exists. It asks similar questions as the prelaunch block, but also determines if the prelaunch attack was successful or not. If the prelaunch attack was successful and the firing TEL destroyed, the calculations for a postlaunch kill are still made, but the result would be zero; no additional TELs are attrited, and no additional ATACMS are expended.

d. Steps 3, 4, 5 - Upper Tier. If the TEL is successful in avoiding attack prior to launch, APAB-PI determines if the TBM successfully launches. This is based on how reliable the TBM and TEL combination are. A successful launch of a TBM targeted against a critical target initiates the first shot try by Upper Tier (UT).

(1) Upper Tier (in this instance THAAD) evaluates each incoming TBM and determines whether or not to engage. The determination to engage is based on an evaluation of the target shot at (if the target is in sector and critical) and the availability of a THAAD interceptor. As an example of the flexibility of the APAB-PI model and the I-THINK software program, after presenting and discussing the initial mental map to the customer, the customer commented that certain types of TBMs cannot be engaged by the THAAD system for a variety of reasons. Taking advantage of the flexibility of the I-THINK program, CAA added a check based on whether or not the incoming TBM was of a type A, D, or F (an unengagable type).

*IF (THAAD_1_Missile_Stock > 0) and (T1_Sector=1) THEN ((1 *Critical?) * (1-TBM_A_In_Flight-TBM_D_In_Flight-TBM_F_In_Flight)) ELSE 0*

(2) After determining if THAAD can (and will) engage, the model then executes a shoot-look-shoot process (Figure 4-3). Successful engagement by the first shot precludes a second. Failure requires the THAAD unit to determine if another THAAD interceptor exists, and if it does, to execute a second shot.

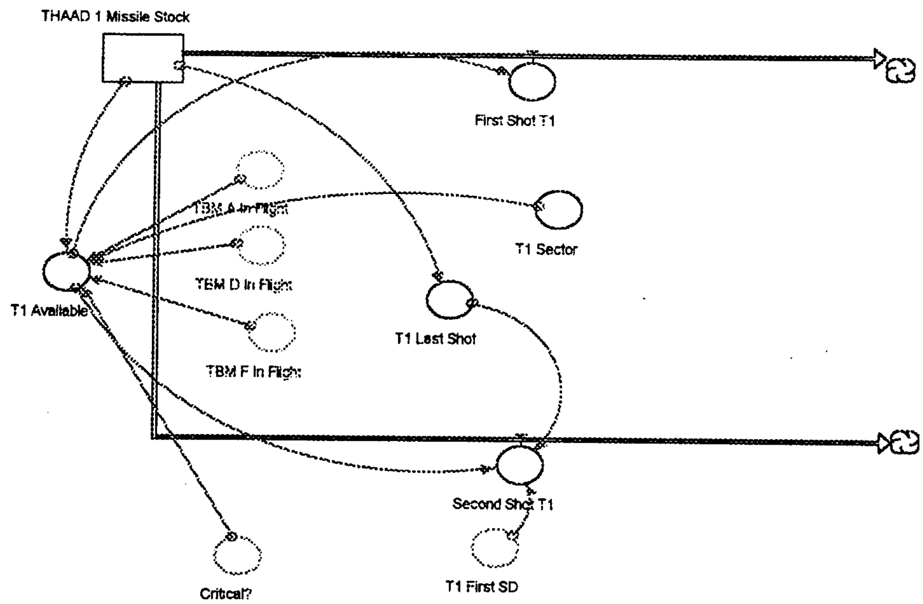


Figure 4-3. THAAD Logic

e. Step 6 - Upper Tier Handoff. If THAAD succeeds in intercepting the TBM, the model calculates the Lower Tier (LT) defense and returns no shots fired and no TBM shot down by lower tier (there is no longer a TBM available to be shot down). If THAAD does not successfully shoot down the TBM, then the Lower Tier sector of the model evaluates the potential success of the specific Lower Tier system defending the target.

f. Step 7 - Lower Tier. The Lower Tier sector (Figure 4-4) begins by evaluating if the TBM fired is approaching one of the targets protected. Critical targets which are close enough to be protected by one Lower Tier firing group are associated into "clusters." Upon successful evaluation of the approach of the TBM, the Lower Tier sector evaluates if the Upper Tier hit or missed (UT Miss). If the Upper Tier missed, then the Lower Tier system will fire if Lower Tier interceptors are available. Because a Lower Tier system may have to be deployed as a single unit without a supporting unit nearby as a backup, the model also evaluates at this time if the Lower Tier system is available, or if it is offline for repairs or maintenance.

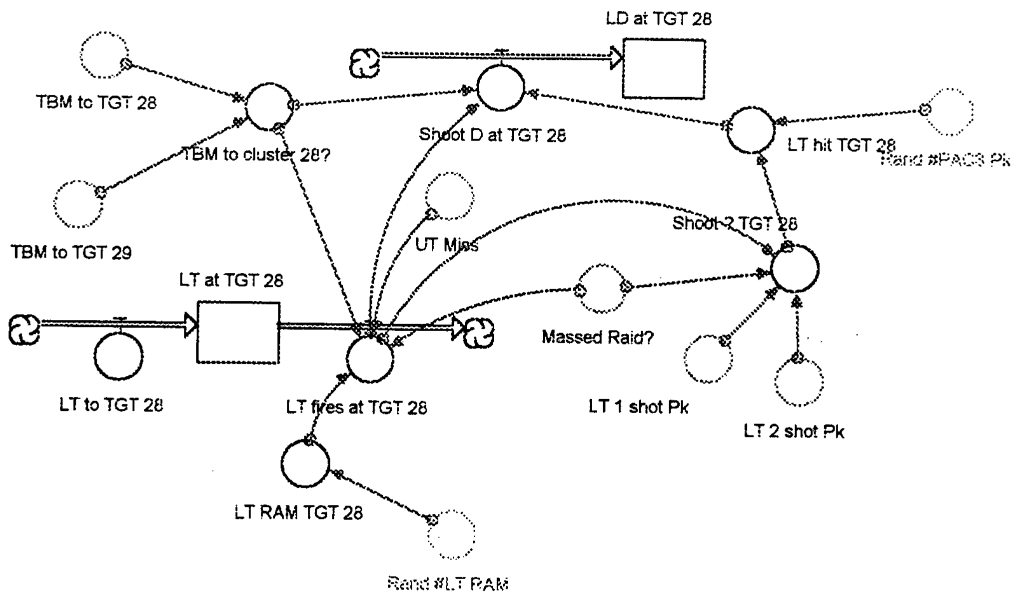


Figure 4-4. Lower Tier Logic

(1) Another evaluation made is if the threat is currently executing a massed raid or not. The APAB-PI model uses dynamic modeling methods to simulate each interval as a single TBM launch. However, the analyst can easily set up massed raid by the threat forces. Under this circumstance, the Lower Tier unit would modify how many interceptors are fired at each successfully arriving TBM.

(2) After determining how many interceptors to fire, the APAB-PI model evaluates the success of the Lower Tier system. If successful, the TBM is shot down. If the Lower Tier misses (as well as the Upper Tier), then the TBM succeeds in arriving at target and is counted as a successful attack. Statistics regarding success and failure of a TBM (and all TBMs) may be defined by the user in any manner desired. This flexibility allows the user to focus on the overall campaign, the attacks against a single cluster of targets, or the success rate and failure rate of a Lower Tier system.

4-4. RESULTS FORMAT

a. Results from APAB-PI are in integer form. For example, for each TBM successfully fired, either the TBM is intercepted and destroyed in flight, or the TBM reaches its intended target. Because several of the critical variables in the model represent random processes, multiple iterations of the scenario are conducted. Each iteration is based on a different random number seed. For a 30-iteration scenario, the output represents success or not for each TBM fired. These results can then be examined in different ways. For example, Figure 4-5 represents the number of TBMs which will successfully arrive for each of five iterations of the random seed generator controlling the probability that the PATRIOT system will destroy an incoming TBM. As shown in this situation, differences are negligible.

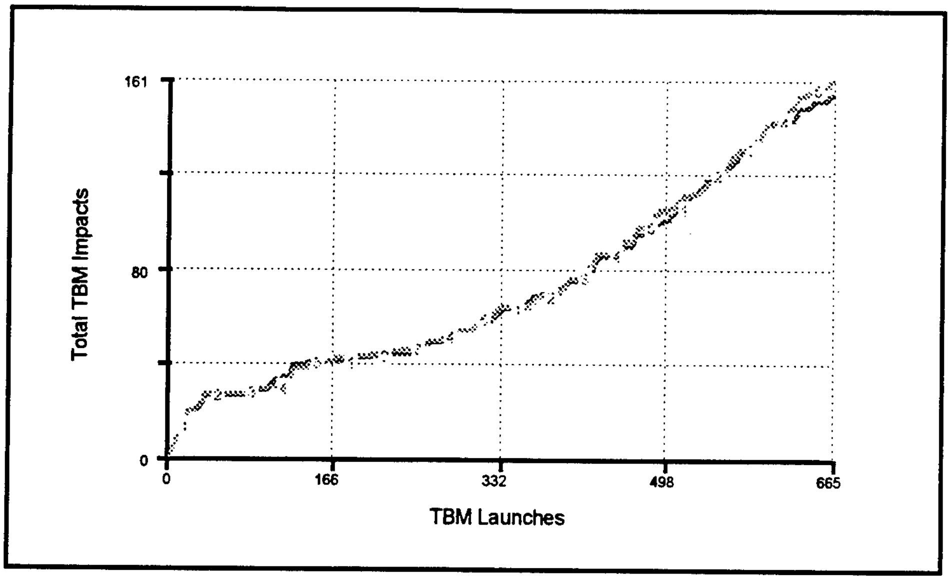


Figure 4-5. TBM Impacts Over Five Different Iterations

b. One common way to evaluate a scenario is to examine the total number of TBMs that successfully reach their assigned target. The output from APAB-PI is quickly transformed into averages for the scenario, histograms, and cumulative distributions for both the entire scenario and over time. For example, while Figure 4-5 is representative of success for each TBM launched, Figure 4-6 presents the average number of TBM impacting by day and a running total over the entire campaign. Since each study to which the APAB-PI model and methodology is applied is unique, measures of effectiveness (MOE) and measures of performance (MOP) will differ. The APAB-PI model generates raw output that represents each step of the model. This output is then exported to a different program (e.g., Microsoft Excel) where MOEs are evaluated.

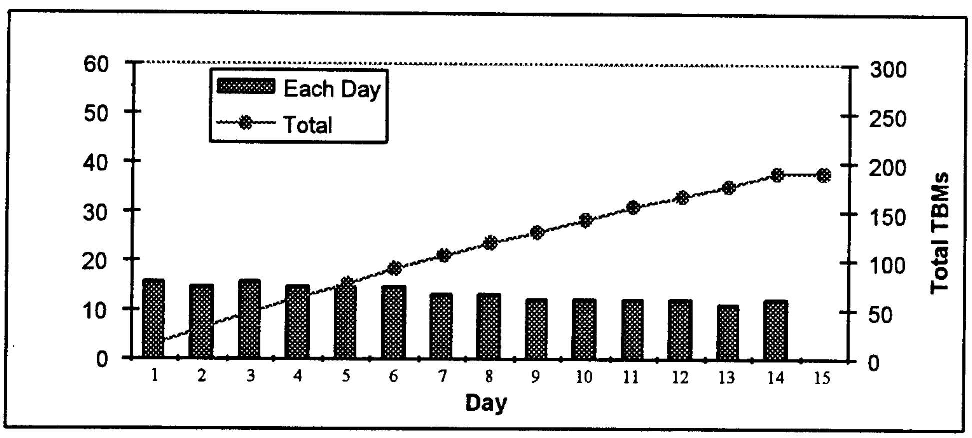


Figure 4-6. TBMs by Day and Total

CHAPTER 5

VERIFICATION AND VALIDATION EFFORTS

5-1. INTRODUCTION. This chapter discusses verification and validation of the APAB-PI model and methodology. Verification occurs when a model produces results that the analyst expects it to produce based on the ligic with which it was built. For example, if a model evaluated the result of 2 + 3, the model would be verified if it returned a 5. Validation occurs when a model produces results which are either expected or match real-world events. For example, the time required to receive radio communications from a sender should be approximately the result of their distance divided by the speed of radio wave propagation.

5-2. VERIFICATION. The nature of the APAB-PI methodology requires constant verification. Models designed to be modified also need to be designed to allow for rapid, detailed, and accurate verification. By its nature, the I-THINK software interface assists in the constantly ongoing verification process.

a. Each interval of the model represents one TBM shot. I-THINK allows a user to identify the occurrences within a model and the actual value of a variable at any given time. By use of the graphical displays, the tabular data displays, and with a numeric display all the stocks, flows, and converters can be evaluated. For example, as shown in Figure 5-1, during many TBM launches late in the campaign, there were no ATACMS missiles available for attack operations against TELs. Similarly, there also were times early in the campaign when no ATACMS missiles were available.

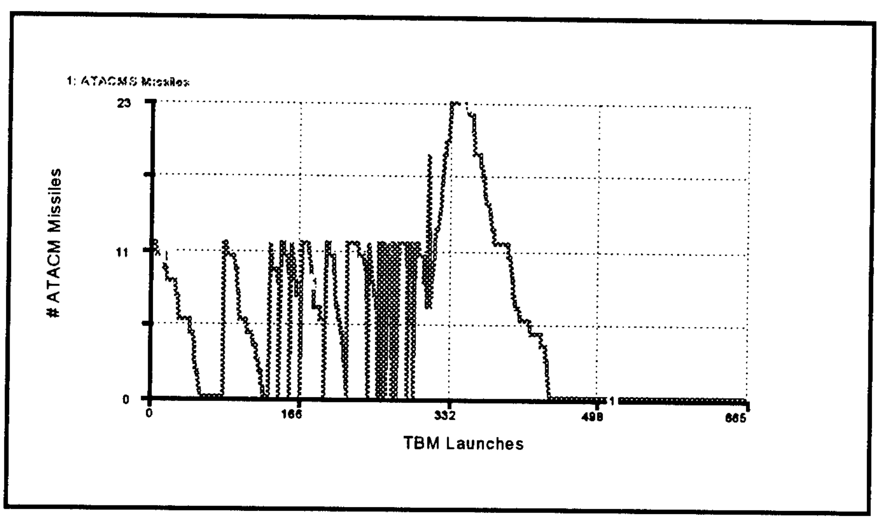


Figure 5-1. Graphical Display

b. Most of the processes within the APAB-PI model are defined as Boolean logic. For example, the decision to fire a Lower Tier interceptor is based on: did Upper Tier miss the incoming TBM, is the TBM of a type which can be intercepted, is the TBM approaching a target defended by the given Lower Tier, are there Lower Tier interceptors available? An example of this logic, as written in the code, looks like:

IF TBM_to_cluster_1? = 1 and Massed_Raid? = 0 and UT_Miss=1 then
*2*LT_RAM_TGT_1 else*
IF TBM_to_cluster_1? = 1 and Massed_Raid? = 1 and UT_Miss=1 then
*1*LT_RAM_TGT_1 else 0*

c. The logic allows for the possible coverage of a massed raid of TBMs. Under a massed raid, the Lower Tier unit would revert to firing only one interceptor at each incoming TBM as opposed to the doctrinal two. This was added when one customer, after being able to visualize the process as a result of the APAB-PI model, realized that a situation might occur in which it would be more advantageous to intercept with only one interceptor at a time. A second idea, incorporating the reliability, availability and maintainability of a system, was added by another customer to better simulate different lower-tier system capabilities.

d. To verify the process is working, a tabular display is set up and evaluated. Each of the inputs to the decision of whether to fire two, one, or zero interceptors is listed. The I-THINK software allows an analyst to have output generated in the table in the same order in which the program executed the model. As a result, verification efforts were able to follow along the same path as the logic within the code. For instance, as mentioned in the lower-tier example above, verification tables can list whether *TBM_to_cluster_*1 first, then list if the raid is a *Massed_Raid*, then if the *UT_Miss*, the *LT_RAM_TGT_*1 value, and then inform the analyst if zero, one, or two interceptors were fired.

5-3. VALIDATION. The I-THINK software program provides an intuitive validation. The mental map which the analyst generates to represent the process is the same map that allows a rapid decision that its components do adequately represent their counterparts in the real world.

a. Output validation answers questions on how well the model results compare with the perceived real world. When APAB-PI was employed in the Southwest Asia Operation Plan (OPLAN) PATRIOT Deployment (SOAP-D) Quick Reaction Analysis (QRA), the ARCENT command concurred that the results were feasible. Internal review within CAA also concurred that the results were feasible. Additional commands within the Army (Space and Strategic Defense Command) also agreed that the results were feasible.

b. The SOAP-D analysis also doubled as a sensitivity analysis for the APAB-PI model. Several targets in the SOAP-D QRA were defended by two units instead of one. It is believed that two units will more adequately protect a target than one unit. The simulation excursions conducted with the APAB-PI model confirmed the thought that a commander, with limited resources, can either protect a few targets well by using two units per target, or a greater number of targets with one unit per target but have less success at defending each given target. From a validation point of view, this change in the inputs to the model produced the expected proportional change in the output. When defensive systems were spread out, fewer TBMs struck targets over the course of the campaign, but those targets that sacrificed some of their defense to provide some protection for other targets saw an increase in the number of TBMs which struck them.

5-4. ONGOING VERIFICATION EFFORTS. Verification efforts are continuously being conducted. As the APAB-PI model is applied to an increasing number of studies, customer enhancements are added. After adding a new enhancement, the model is reverified. Validation efforts are also continuously being conducted. As APAB-PI supports more studies, the results of the studies are evaluated both internal to CAA as well as with the customer. In this way the question, "Does it make sense?" is asked time and again.

APPENDIX A

STUDY CONTRIBUTORS

A-1. STUDY TEAM

a. Study Director

Mr. Karsten Engelmann

A-2. PRODUCT REVIEW BOARD

Mr. Ronald J. Iekel, Chairman
LTC Robert C. Bailey
Mr. William K. Wright

APPENDIX B

STUDY DIRECTIVE

DEPARTMENT OF THE ARMY
U. S. ARMY SPACE AND STRATEGIC DEFENSE COMMAND
POST OFFICE BOX 15280
ARLINGTON, VIRGINIA 22215-0280

REPLY TO
ATTENTION OF

CSSD-OP

MEMORANDUM FOR Director, US Army Concepts Analysis Agency,
8120 Woodmont Avenue, Bethesda, MD 20814

SUBJECT: APAB-PI Study Directive

1. PURPOSE. This directive establishes objectives and provides guidance for the conduct of the Active, Passive, Attack Operation, BM/C4I Pillar Integration (APAB-PI) study.

2. BACKGROUND

a. An increasing number of countries have or will have theater missile (TM) and unmanned aerial vehicle (UAV)/remotely piloted vehicle (RPV) capabilities. Theater missiles include ballistic missiles, cruise missiles, and air-to-surface missiles whose targets are within a given theater of operations. These capabilities, coupled with the unpredictability of potential adversaries and potential use of weapons of mass destruction (WMD) represent a serious threat to US deployed, allied, and coalition forces, population centers, and critical assets worldwide. The proliferation and sophistication of the threat will overwhelm the current theater missile defense (TMD) capabilities of the US and its allies.

b. Theater missile defense is considered to have four elements which are all key to the successful neutralization of an enemy's missile capability: Active Defense, Passive Defense, Attack Operations represent the three pillars of TMD. Underlying these three pillars is a coordinating base called Battle Management/Command, Control, Communications, Computers and Intelligence (BM/C4I).

(1) Active Defense includes those operations initiated to protect against a TM attack by destroying airborne TM launch platforms and/or destroying TMs in flight. Active Defense forces currently consist of the Patriot anti-tactical ballistic missile system, soon to be upgraded to the Patriot Advanced Capability-3 (PAC-3). The Army is developing the long range Theater High Altitude Area Defense (THAAD) system to provide an Upper Tier defense against TMs. The PAC-3 system will provide a Lower Tier defense against TMs. The Medium Extended Range Air Defense System (MEADS), also known as the Corps Surface to Air Missile (CorpsSAM), will provide protection against TMs for maneuver units. The Improved Hawk system is also being upgraded to give it limited anti-tactical ballistic missile (ATBM) capability for use by the US Marine Corps. The US Navy is developing sea-based Lower Tier (SM-Blk IVa) and Upper Tier (Light Exoatmospheric Projectile) TMD capabilities. The US Air Force is proposing a Boost Phase Intercept (BPI) concept that could include either an interceptor missile, and airborne laser, or both.

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(2) Passive Defense includes those measures taken to reduce vulnerability and to minimize the effects of damage caused by TM attack. These include early warning and WMD protection, counter-surveillance, deception, camouflage and concealment, nuclear hardening, electronic warfare (EW), mobility, dispersal, redundancy, recovery and reconstitution.

(3) Attack Operations are those operations initiated to neutralize, destroy, or disrupt TM launch platforms and supporting command, control and communications, computers and intelligence (C4I), logistics infrastructure, and reconnaissance, surveillance and target acquisition (RSTA) platforms. Attack operations forces include USAF and USN attack aircraft, the Army Tactical Missile System (ATACMS) and Multiple Launch Rocket System (MLRS), attack helicopters, unmanned aerial vehicles (UAVs), and Special Operations Forces (SOF).

(4) TMD BM/C4I represents the integrated system of doctrine, procedures, organizational structures, facilities, communications, computers, and supporting intelligence. BMC4I includes missile warning and cueing of defense systems by missile warning sensors and ground stations, as well as the entire suite of sensor and intelligence systems capable of supporting TMD. BM/C4I provides command authorities at all levels with timely and accurate systems and data to plan, monitor, direct, control, and report TMD operations.

c. There is currently little formalized doctrinal or hardware integration of forces and elements representing the TMD pillars, even within the Services. Army Attack Operations and Active Defense forces are not fully integrated with existing sensors, C4I systems, and early warning systems to provide a synchronized response by all four TMD elements to a TM attack. As improved TMD capable systems become operational, military forces will require appropriate doctrine to define the communications architectures and protocols needed to employ Service capabilities in a timely manner, and the responsibilities of various components in responding to TM attacks.

d. There is a strong desire within the TMD community for a low resolution, fast turn-around model. Most current TMD models examine high resolution, single strike scenarios. However, few models exist that examine all strikes during an entire campaign, hence the development of the APAB-PI model.

3. STUDY SPONSOR. U.S. Army Space and Strategic Defense Command (USASSDC).

4. STUDY AGENCY. U.S. Army Concepts Analysis Agency (CAA).

5. STUDY PURPOSE. Develop a methodology to evaluate integrated Army Theater Missile Defense operations to protect maneuver forces and critical assets.

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6. OBJECTIVE.

a. Represent components of an integrated TMD campaign.

b. Demonstrate the ability to conduct analysis of the TMD campaign using an established TMD scenario.

7. SCOPE.

a. The I-THINK dynamic modeling software package will be used to develop the APAB-PI model.

b. A current TMD scenario will be used to demonstrate methodology.

(1) Scenario - Southwest Asia.

(2) Time frame - 1996.

(3) Defending Forces - Gulf Allied and U.S. deployed forces.

(4) Attacking Forces - Iran.

8. ASSUMPTIONS.

a. I-THINK dynamic modeling techniques can effectively represent integrated TMD.

b. The scenario selected to demonstrate the APAB-PI methodology accurately depicts likely circumstances under which US forces might become engaged in conflict in the specified time frame. This includes the allied and threat forces, US force structure and modernization, munitions availability and strategic lift asset availability.

9. LIMITATIONS.

a. The APAB-PI methodology does not capture weapon systems characteristics in detail.

b. Performance characteristics of future TMD systems will be estimated from available system descriptions, Operational Requirements Documents (ORD) and other sources.

10. RESPONSIBILITIES.

a. USASSDC will designate a point of contact (POC) for oversight of the study, to

CSSD-OP
SUBJECT: APAB-PI Study Directive

provide guidance on study objectives and priorities, and to provide assistance as required.

b. CAA.

(1) Will provide the study team, conduct the study, present emerging and final results to the sponsor and organizations specified by the sponsor, and publish the study report.

(2) Will coordinate data required through USASSDC or other agencies as needed.

11.. LITERATURE SEARCH. A thorough literature search was performed. Documents and reports of previous work on the subject were ordered for review.

12. REFERENCES.

a. Joint Pub 3-01.5, Doctrine for Joint Theater Missile Defense, 30 March 1994.

b. Defense Planning Guidance, FY 1996-2001.

c. Integrated Battlefield Targeting Architecture.

13. ADMINISTRATION.

a. Travel and per diem funds that may be required for data collection and coordination in support of the conduct of this study will be provided by USASSDC.

b. The I-THINK dynamic modeling software required to build the model and support the study will require the use of Macintosh and IBM PC computers existing at CAA. Portable Macintosh computers will be required to conduct and present simulations on the road.

c. The study schedule follows:

(1) Data Collection Dec 1995 - June 1996.

(2) Simulation and Analysis June 1996 - July 1996.

(3) Results Briefing and Report no later than 30 Aug 1996.

Darrell W. Collier

Darrell W. Collier
Chief Scientist

APPENDIX C

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APPENDIX D

DISTRIBUTION

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GLOSSARY

1. ABBREVIATIONS, ACRONYMS, AND SHORT TERMS

AG	above ground
APAB-PI	Active, Passive, Attack Operations - Pillar Integration (study)
ATACMS	Army Tactical Missile System
ATBM	antitactical ballistic missile
BMC4I	battle management, command, control, communications, computers, and intelligence
BMDO	Ballistic Missile Defense Office
BPI	boost phase intercept
C4I	command, control, communications, computers, and intelligence
CAA	US Army Concepts Analysis Agency
COEA	cost and operational effectiveness analysis
EADSIM	Extended Air Defense Simulation computer model
ERINT	extended range interceptor
EW	electronic warfare
IBM	International Business Machines, Inc.
LD	Lower Tier downed
LT	Lower Tier
MEADS	Medium Extended Range Air Defense System
MLRS	multiple launch rocket system
MOE	measure(s) of effectiveness
MOP	measure(s) of performance
NBC	nuclear, biological, and chemical
ORD	operational requirements document
PAC-2	PATRIOT Antitactical Missile Capability - Level 2
PAC-3	PATRIOT Antitactical Missile Capability - Level 3

PC	personal computer
POC	point of contact
RAM	reliability, availability, and maintainability
RPV	remotely piloted vehicle
RSTA	reconnaissance, surveillance, and target acquisition
SAM	surface-to-air missile
SCUD	Soviet surface-to-surface missile
SHORAD	short-range air defense
SOF	Special Operations Forces
SSDC	US Army Space and Strategic Defense Command
SSPK	single shot probability of kill
TBM	tactical ballistic missile
TEL	transporter/erector/launcher
TGT	target
THAAD	Theater High Altitude Area Defense
TM	theater missile
TMD	theater missile defense
UAV	unmanned aerial vehicle
UG	under ground
USAF	US Air Force
USASSDC	US Army Space and Strategic Defense Command
USN	US Navy
UT	Upper Tier
WMD	weapons of mass destruction

2. MODELS, ROUTINES, AND SIMULATIONS

APAB-PI	Active, Passive, Attack Operations, BMC4I - Pillar Integration Model
I-THINK	computer program, High Performance Systems, Inc., replaced older version known as STELLA II
STELLA II	computer program, High Performance Systems, Inc., superseded by I-THINK